



# Progress in the Construction of the MICE Cooling Channel

NuFact'11 XIIIth Workshop on Neutrino Factories,  
Superbeams and Beta-beams  
CERN/University of Geneva  
Geneva, Switzerland  
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Gail G. Hanson, University of California, Riverside  
On Behalf of the MICE Collaboration

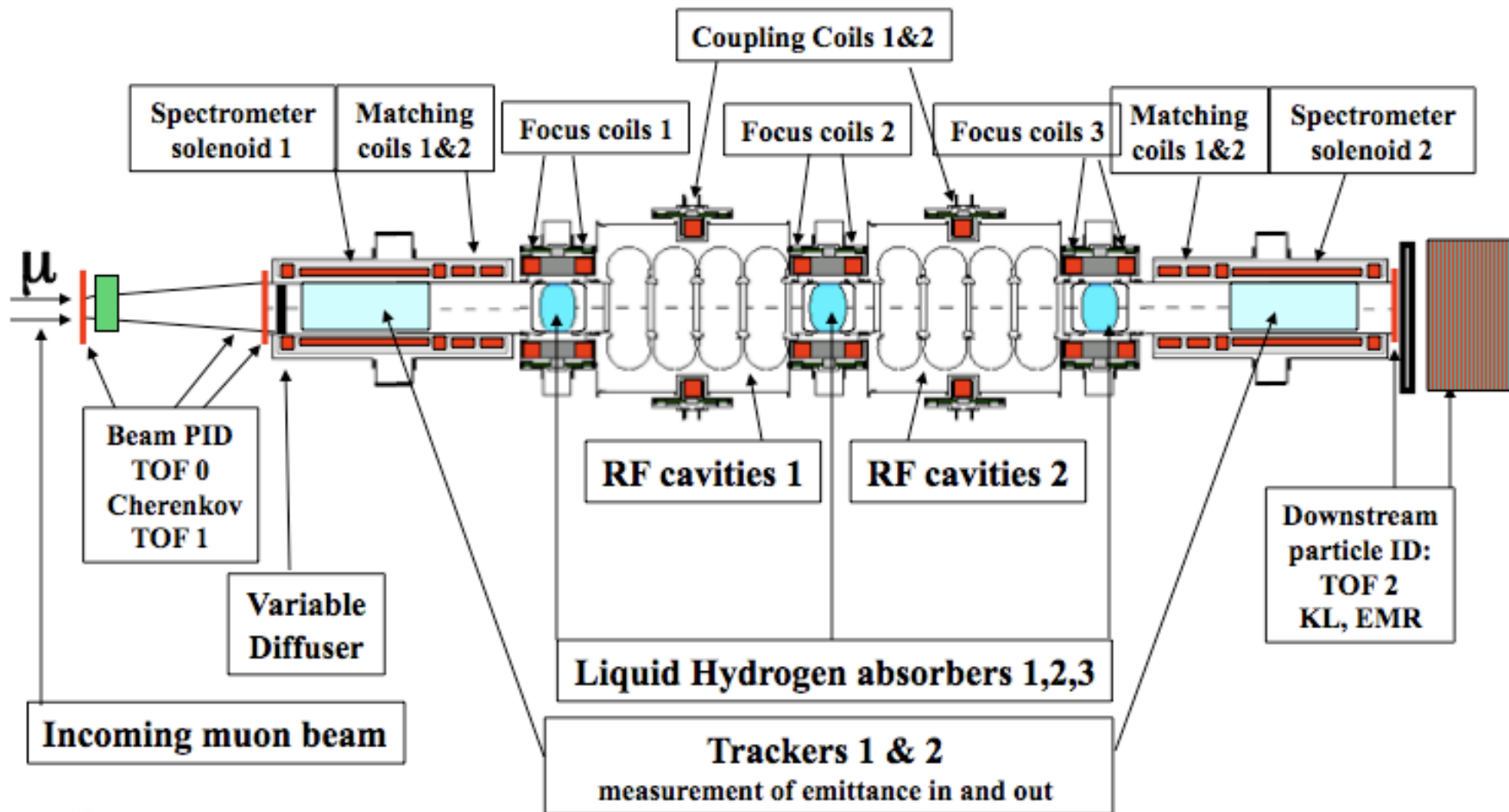


# OUTLINE

- MICE Layout and Goal
- Step IV
- Step V
- Step VI
- Summary of MICE Schedule Steps IV-VI
- Summary and Conclusions

# MICE LAYOUT

Goal: Measure 10% emittance reduction to within 1% – an absolute emittance measurement to within 0.1%





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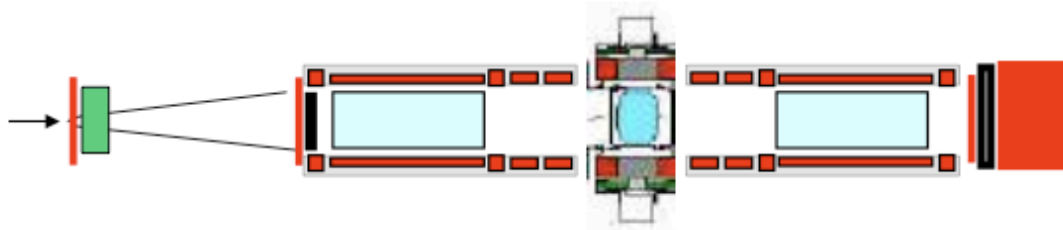
**MICE SCHEDULE -- update July 2011**

**Run date:**

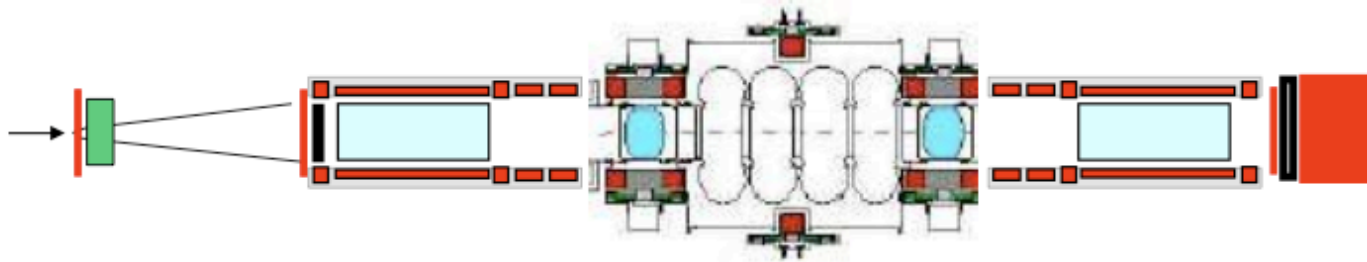


**STEP I**

**completed -> Aug2010  
EMR run Q1 2012**

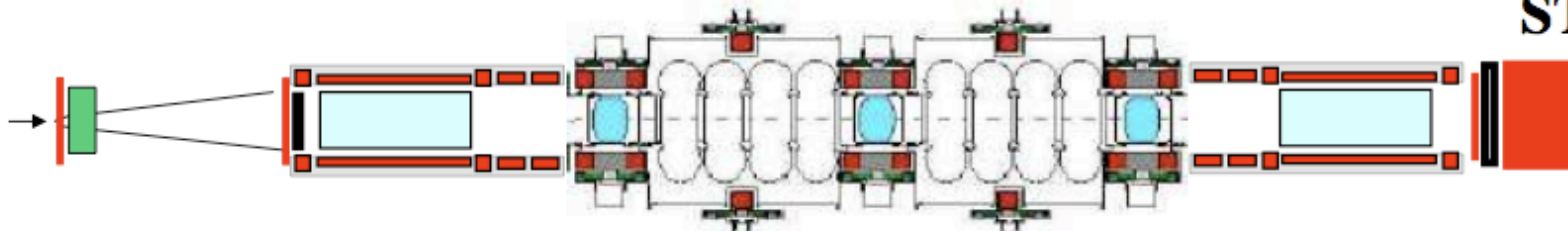


**STEP IV Q3 2012**



**STEP V**

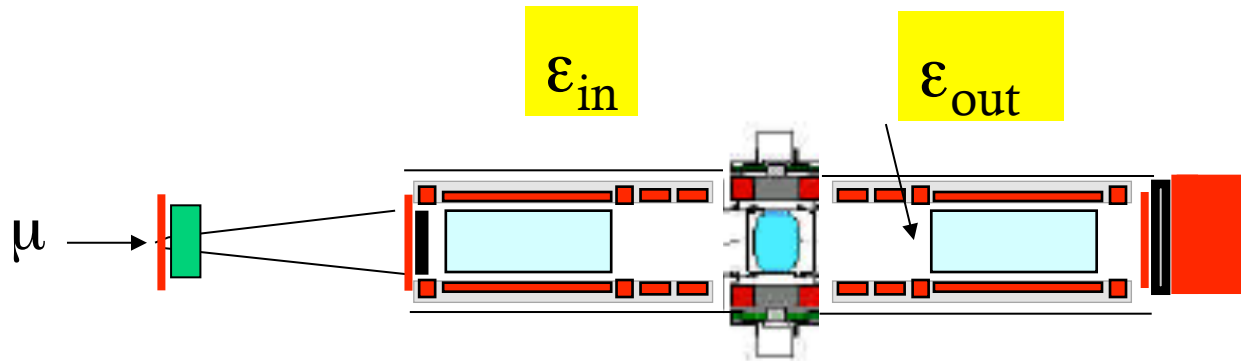
*Q2 2014 \*)*



**STEP VI**

*\*) target date, necessary to run step V before long ISIS shut-down Aug.2014-Feb.2015*

# STEP IV

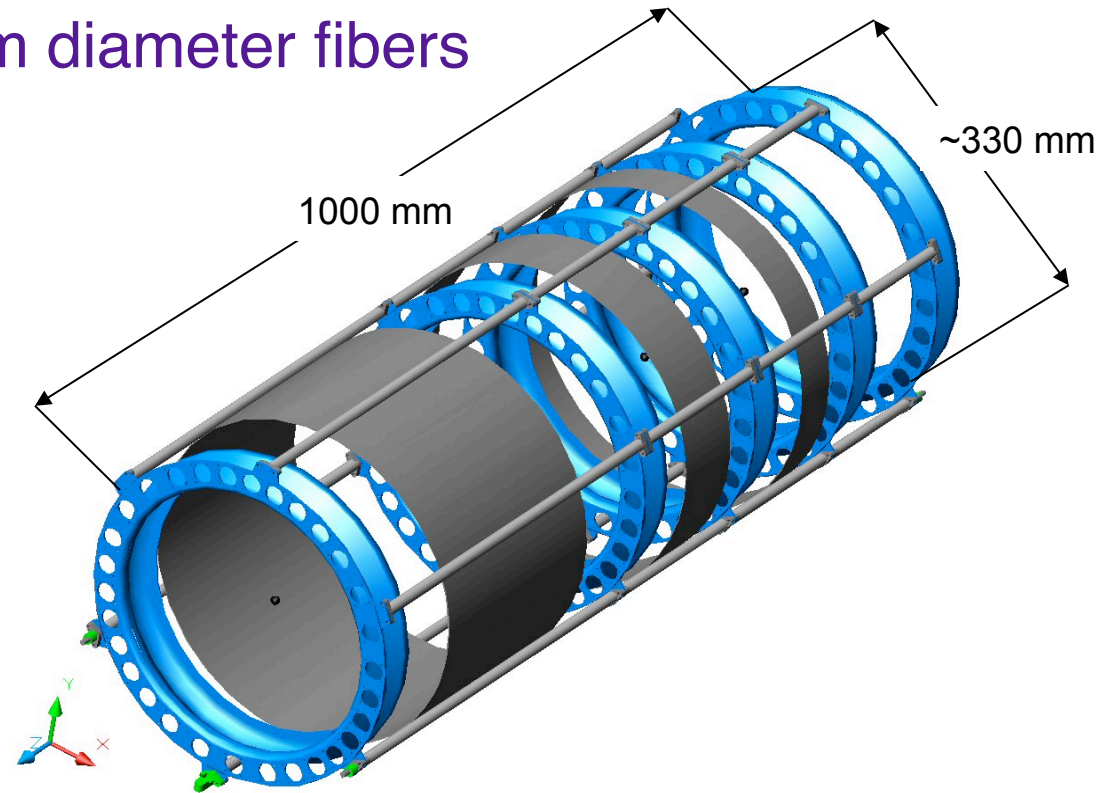
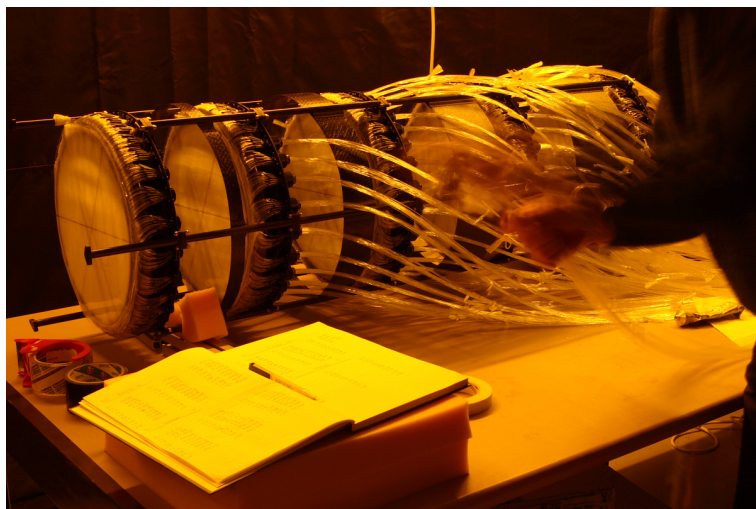


- Goal: measure  $\epsilon_{in} / \epsilon_{out}$
- Install spectrometer solenoids, trackers, absorber by 2012 Q3; commission; data taking Q4 2012 – Q1 2013
- Absorbers (possible order):
  1. Liquid  $H_2$  absorber empty
  2. Liquid  $H_2$  absorber full (liquid He option) – will have measured ionization cooling
  3. Vacuum (only He and windows for trackers)
  4. Solid absorbers (flat LiH, wedge LiH – emittance exchange, other solid absorbers)

## Trackers:

(Japan, UK, US)

- Two identical trackers with 5 planes of 3-views
- 440  $\mu\text{m}$  point resolution achieved
- Scintillating fiber detector with VLPC readout
- 7-fold ganging of 350- $\mu\text{m}$  diameter fibers



# STEP IV (continued)



## Emittance measurement – single particle measurements:

Each spectrometer measures 6 parameters per particle

$$x \quad y \quad t$$

$$x' = dx/dz = P_x/P_z \quad y' = dy/dz = P_y/P_z \quad t' = dt/dz = E/P_z$$

Determines, for an ensemble (sample) of N particles, the moments:

Averages  $\langle x \rangle$   $\langle y \rangle$  etc...

Second moments: variance(x)  $\sigma_x^2 = \langle x^2 - \langle x \rangle^2 \rangle$  etc...

covariance(x)  $\sigma_{xy} = \langle x \cdot y - \langle x \rangle \langle y \rangle \rangle$

Covariance matrix

$$M = \begin{pmatrix} \sigma_x^2 & \sigma_{xy} & \sigma_{xt} & \sigma_{xx'} & \sigma_{xy'} & \sigma_{xt'} \\ \dots & \sigma_y^2 & \dots & \dots & \dots & \sigma_{yt'} \\ \dots & \dots & \sigma_t^2 & \dots & \dots & \sigma_{tt'} \\ \dots & \dots & \dots & \sigma_{x'}^2 & \dots & \sigma_{x't'} \\ \dots & \dots & \dots & \dots & \sigma_{y'}^2 & \sigma_{y't'} \\ \dots & \dots & \dots & \dots & \dots & \sigma_{t'}^2 \end{pmatrix}$$

Getting at e.g.  $\sigma_{x't'}$  is essentially impossible with multiparticle bunch measurements

Evaluate emittance with:  $\epsilon^{6D} = \sqrt{\det(M_{xytx'y't'})}$

Compare  $\epsilon^{in}$  with  $\epsilon^{out}$

$$\epsilon^{4D} = \sqrt{\det(M_{xyx'y'})} = \epsilon_{\perp}^2$$

# STEP IV (continued)



## Spectrometer solenoids:

- Management directly under LBNL Head of Accelerator and Fusion Research Division → substantial increase in resources
- Good MICE magnet coordination established
- Reconsiderations of issues of large magnet for cryocooling plus EM coupling between coils led to better solutions for thermal balance and quench protection of magnet/leads
- Plan and milestones for Step IV running established

Spectrometer Solenoid  
(Wang NMR)



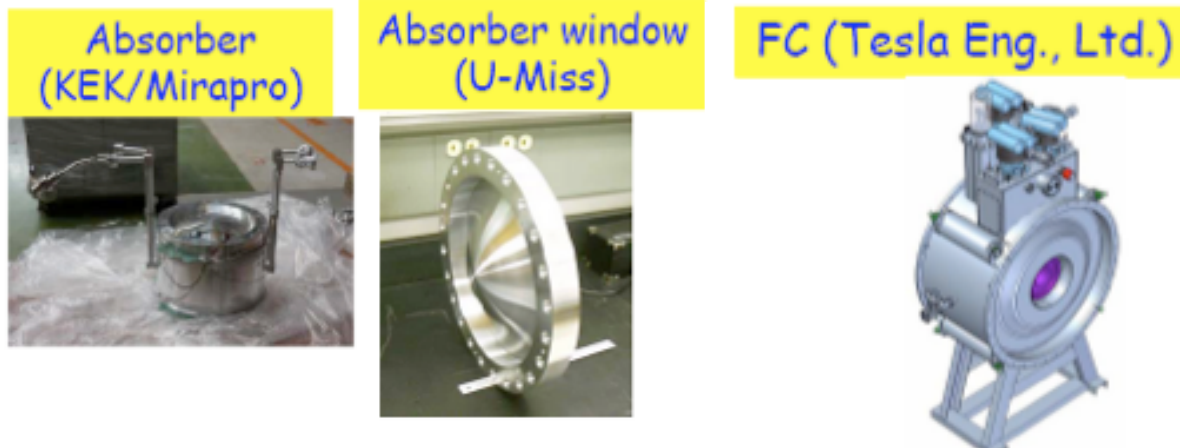


# STEP IV (continued)



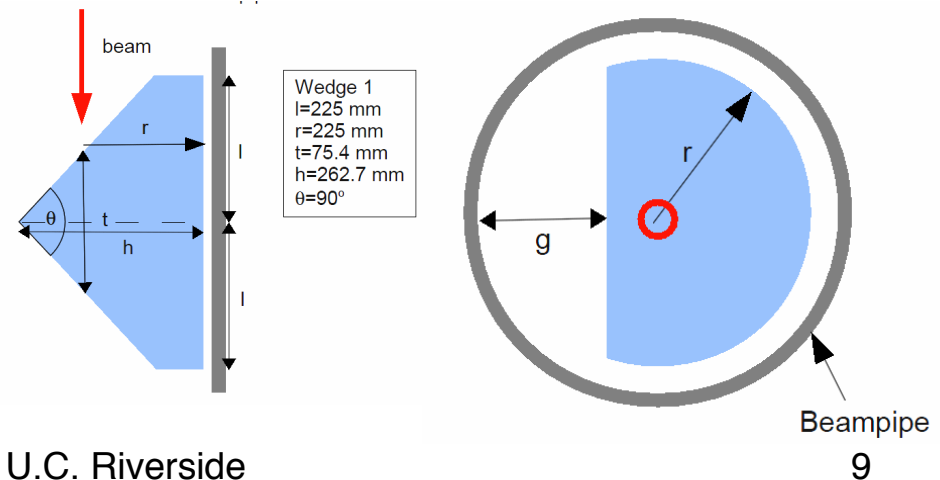
## Absorbers:

- Liquid hydrogen absorber – good progress on absorber, focus coil, and LH<sub>2</sub> system

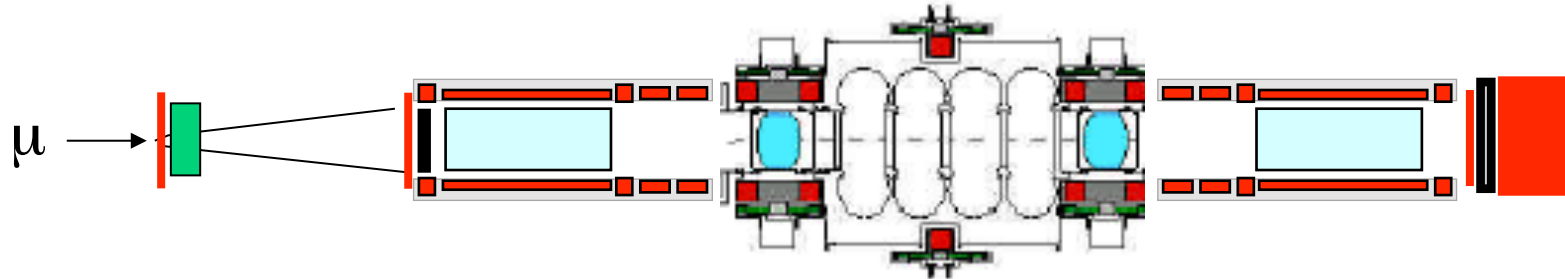


- Wedge absorber

## Emittance exchange demonstration



# STEP V



- Goal: gain experience with RFCC module operation in MICE system
- Production of cooled beam requires acceleration with RF cavities
- Requires:
  - RF cavities
  - RF power
  - RF controls and connections, etc.
  - Coupling coil
- Aim to take Step V data before long ISIS shutdown August 2014 – February 2015; Step IV will end in time for installation – depends on RFCC delivery

# STEP V (continued)



## Coupling Coils

- First coil has been wound at Qi Huan (China) and shipped to HIT/ICST in June 2011
- Welding of cold mass cover plate at HIT
- Ship to US – tentative plan to test coil in cryostat at Fermilab – test of first coil is critical!
- Order more conductor for remaining coils
- Design for quench protection and leads
- Management directly under LBNL Head of Accelerator and Fusion Research Division → substantial increase in resources

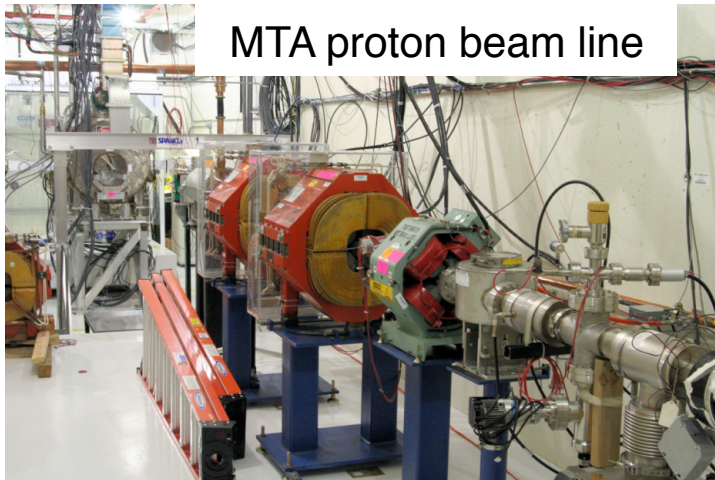


# STEP V (continued)

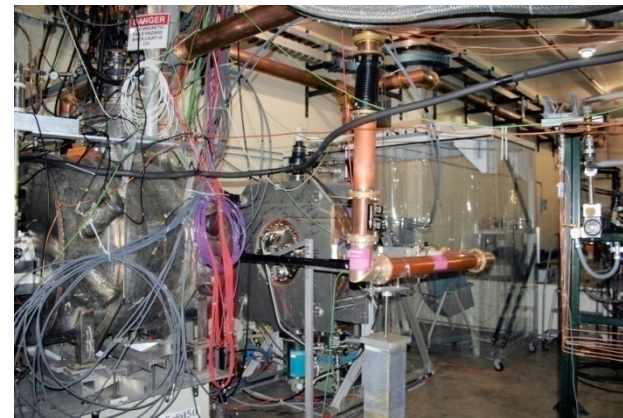


## RF Cavities

- RF cavity production advancing well
  - 10 (8 + 2) cavity bodies delivered to LBNL
  - 9 TiN coated Be windows delivered and accepted
  - Single cavity test module designed and will be tested at FNAL
- Problem of RF cavity breakdown in high magnetic field under investigation at FNAL MuCool Test Area (MTA)
  - crucial test awaits coupling coil



MTA proton beam line

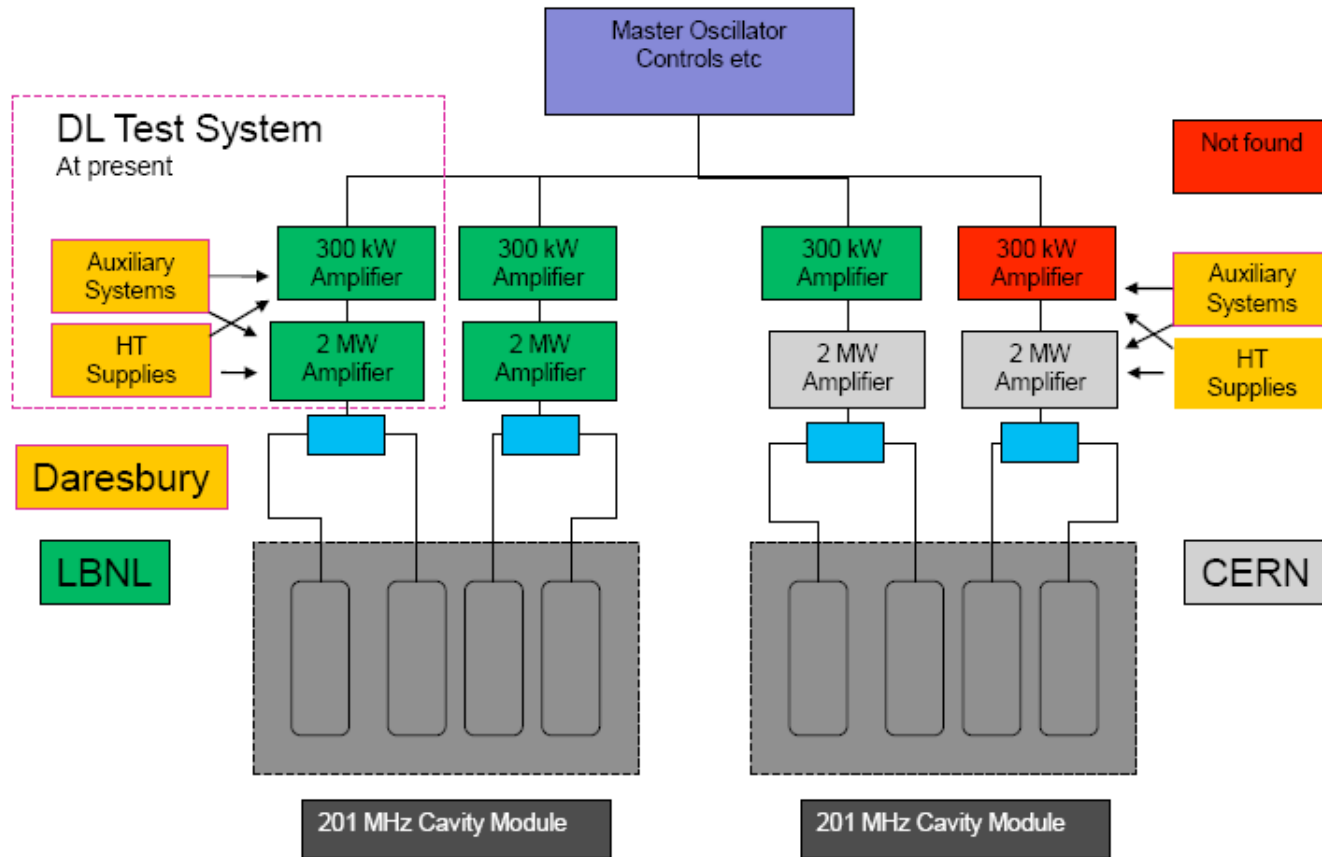


201 MHz RF testing

## RF Power and Infrastructure



### RF system components



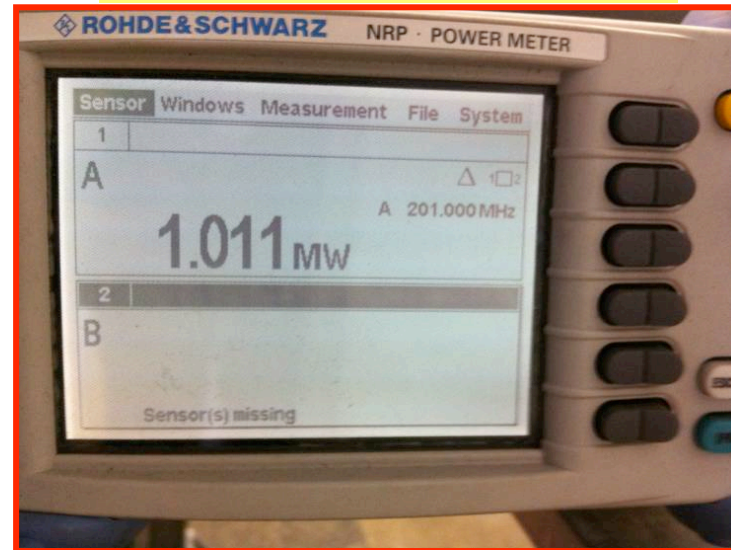
# STEP V (continued)



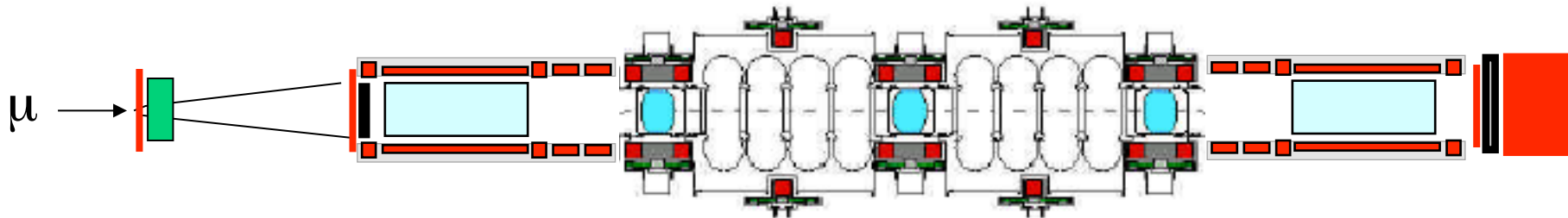
## RF Power

- “LBNL” unit refurbished. System pushed to 1 MW RF output
- Relatively quiet: No evidence of significant X-ray production  
- will now continue to push towards 2 MW
- Next the CERN RF unit will be reassembled and tested.  
→ 2+2= 4 MW

Forward power into load



# STEP VI



- Full cell of the cooling channel
- Optics and performance needed for 10% cooling measurement
- Study performance of Study II cooling channel
- If Step V RFCC not ready before long shutdown, will consider proceeding directly to Step VI (there are some risks involved)



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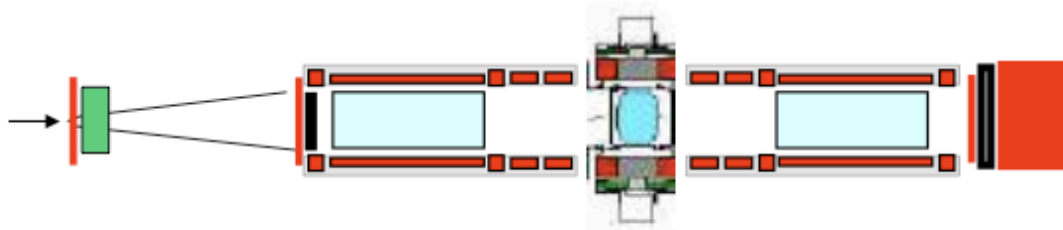
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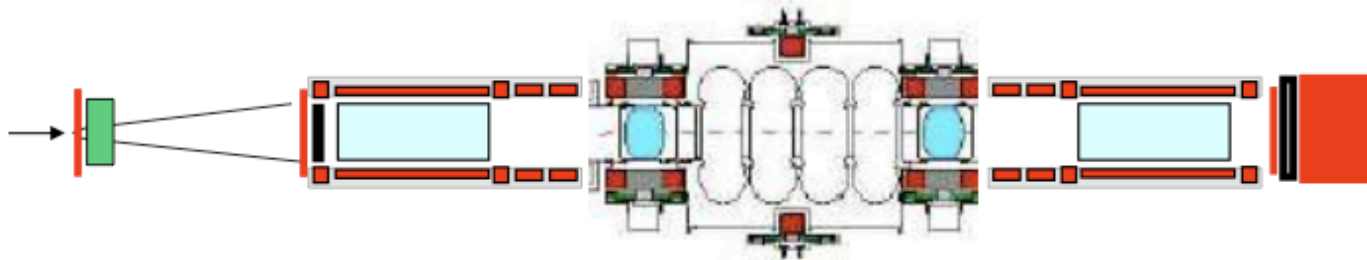


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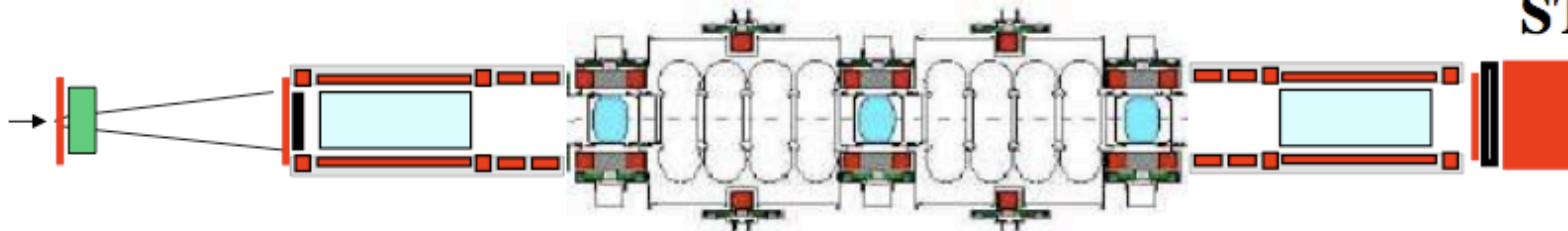


**STEP IV Q3 2012**



**STEP V**

*Q2 2014 \*)*



**STEP VI**

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## SUMMARY AND CONCLUSIONS

- Good progress on re-baselined MICE schedule
- Plan and milestones established for spectrometer solenoids for Step IV in October 2012
- MICE aims to take data in Step V mode before ISIS long shutdown August 2014
- Coupling coils critical – schedule depends on cryostat test of first coil
- MICE is on the way towards demonstrating ionization cooling!